Driver Offers Proportional Solenoid Control Without PLC, Microcontroller

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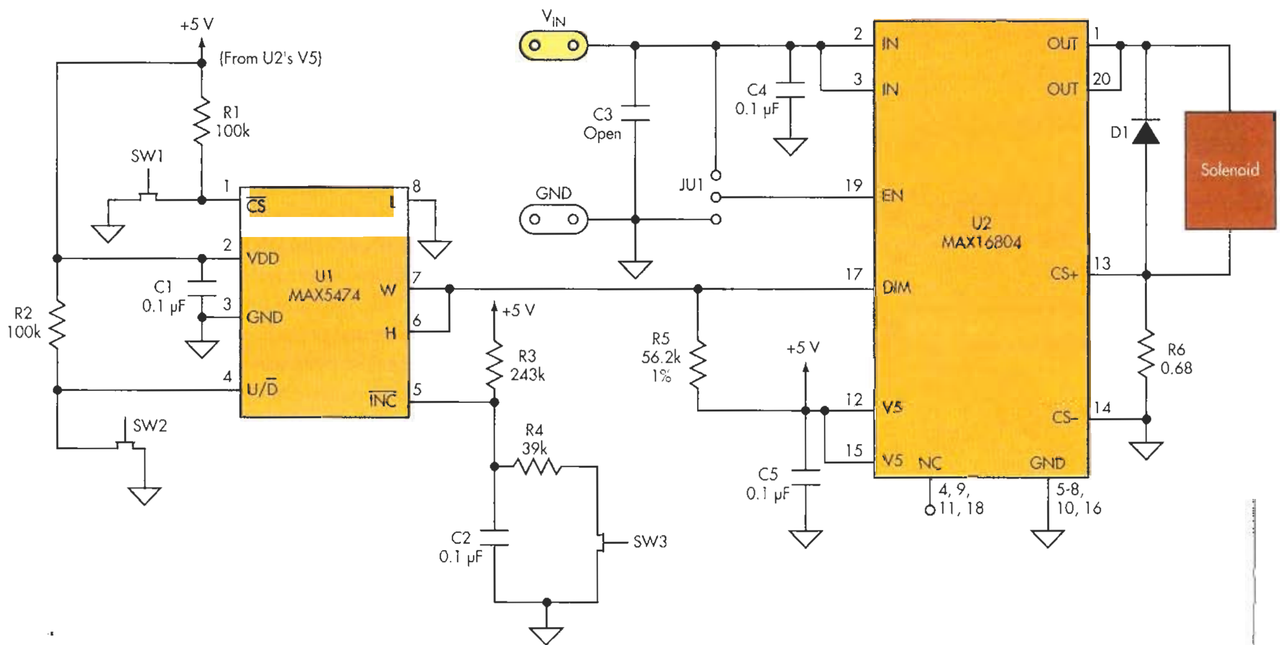


1. This small, surface-mount, digital-driver circuit provides proportional drive for a solenoid, eliminating the need for a microcontroller or a programmable logic controller.

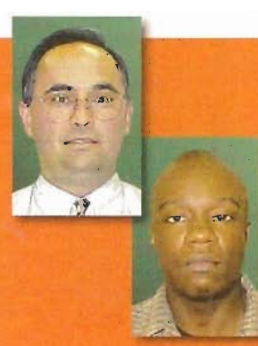
The proportional-control solenoids used in some industrial hydraulic systems are usually driven by microcontrollers or programmable logic controllers (PLCs). Such complex drivers typically require several different supply voltages for logic and control. (The purpose of proportional control is to move the solenoid plunger to an arbitrary position and leave it there.) A set-and-leave solenoid driver, however, should not require a costly PLC or the processing power of a microcontroller. Ideally, it should operate from the solenoid's own supply voltage.

The circuit in Figure 1 meets these requirements while occupying only a small surface-mount footprint. U2 is a 350-mA driver with built-in analog and pulse-width-modulation (PWM) dimming control. It's typically used to drive high-brightness LEDs, but in this application, its open-drain output (OUT) and current-sense terminal (CS+) connect directly to the solenoid terminals. R6 sets the maximum solenoid current.

The circuit drives solenoids ranging from 6 to 40 V dc, using only the solenoid's 6- to 40-V dc source. The circuit was tested using a LEDex 24-V pull-solenoid rated for currents up to 290 mA.

U1 is a 32-tap, nonvolatile, linear-taper digital potentiometer. Connected as a variable resistor, its internal 100-kΩ variable resistance forms a divider with R5 to produce a 0- to 3.17-V analog voltage at U2's DIM input. After activating the potentiometer by depressing SW1 and setting the direction of change using SW2 (Open for up, Closed for down), you can increment this DIM voltage with each toggle of SW3 (with SW1 closed). Thirty-two steps are available, so 32 press-and-release cycles of SW3 traverse the range from 0 to 3.17 V. In terms of wiper position, the approximate voltage at DIM (V_{DIM}) is:

$$V_{DIM} \approx 5\,V[(N-1)3225.8\,\Omega]/[(N-1)3225.8\,\Omega + R5]$$



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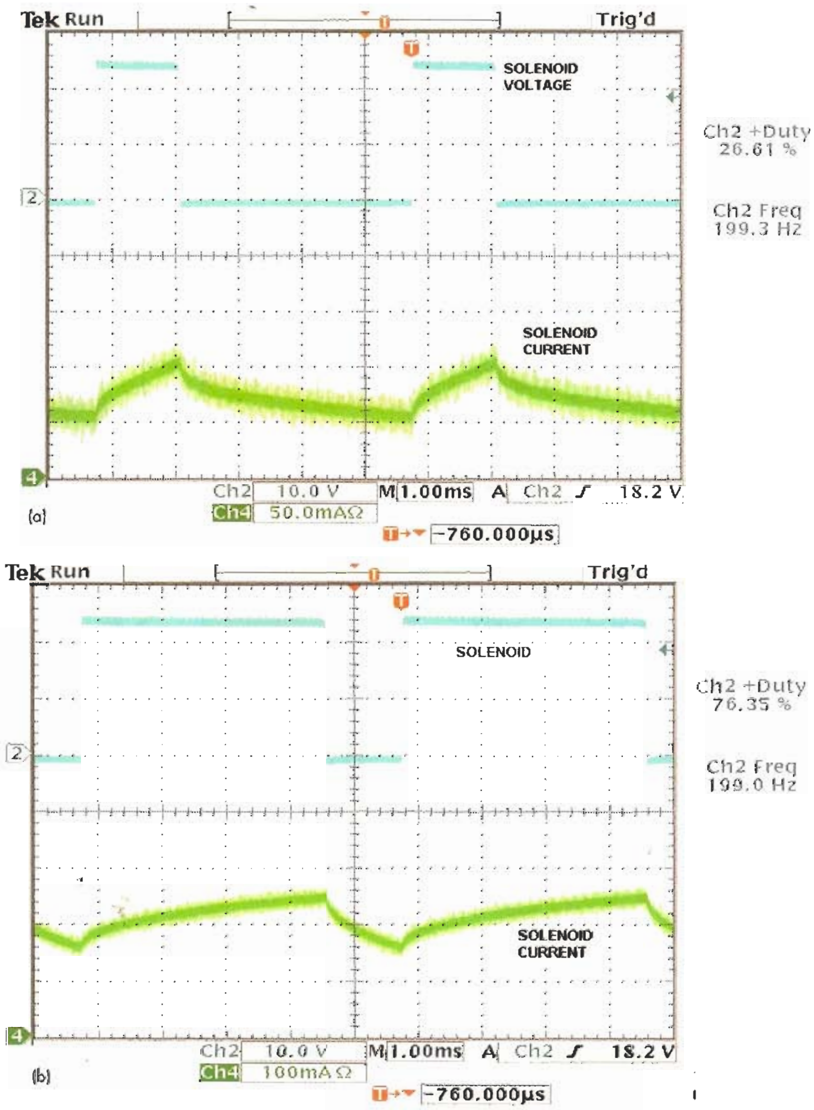

2. These solenoid voltage and current waveforms from the driver circuit produce plunger distances of 0.0312 in. and 0.3215 in. for a 26% duty cycle (a) and a 76% duty cycle (b), respectively.

where R5 = 56.2 kΩ and N is the Nth wiper step (between 0 and 32). R3, R4, and C2 debounce the SW3 pulses that increment/decrement the wiper. U2 switches the solenoid at 200 Hz, with a PWM duty cycle that varies with the voltage at the DIM pin.

U2 is powered by the solenoid's power supply (24 V in this case). U1 is powered by U2's V5 pin, a 5-V supply that can source as much as 2 mA. Capacitors C1, C4, and C5 bypass the supply voltages at their respective IC pins. A bulk-holdup capacitor (C3) may be needed if the circuit is located at a distance from the dc source. To accommodate the PWM action applied by U2, freewheeling diode D1 allows current to circulate through the solenoid coil each time its power switches off (200 times per second).

U2 provides indirect short-circuit and thermal protection to guard its output against overcurrent and short-circuit conditions created by a defective solenoid or shorted leads. Jumper JU1 controls U2 by connecting its EN input (pin 19) to V_{IN} (enable) or GND (disable). The table summarizes the circuit's conditions for various positions of the solenoid.

Figure 2a shows the solenoid-driver voltage and current pulses produced when the circuit operates at a 26% duty cycle. That duty cycle represents the solenoid voltage and the 32.4-mA rms current required to energize the solenoid coil and pull in the solenoid plunger a distance of 0.0312 in.

Figure 2b shows the solenoid-driver voltage and current pulses at a 76% duty cycle, which represents the solenoid voltage and 211-mA rms current needed to energize the solenoid coil and pull in the solenoid plunger a distance of 0.312 in.

Solenoid-Driver Circuit Data

V_{IN} (V rms)	Solenoid travel (in.)	DIM pin voltage (V dc)	Solenoid pull-in current (mA rms)	Duty cycle (%)	Solenoid pull-out current (mA rms)
24.00	0.4375	2.752	245	90.4	22.2
24.00	0.3125	2.424	221	76.1	10.6
24.00	0.25	1.991	143	64.3	10.3
24.00	0.1875	1.657	104.1	52.6	10.2
24.00	0.125	1.392	79.1	43.64	10.2
24.00	0.0625	1.083	48.6	32.8	10.2
24.00	0.0312	0.909	39.2	26.9	10.2